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VIII.—*On the past and present Water supplies of Calcutta.*—*By* ALEXANDER PEDLER, F. I. C., F. C. S., London and Berlin.

At the present day it is I believe universally acknowledged, that every town should be provided with a pure and sufficient supply of water for drinking, domestic and sanitary purposes. If the quantity be not sufficient or if the quality be not good, it may be safely asserted that injury, more or less profound, to the general health of its inhabitants will be the consequence. The very great importance which is attached to the quality and quantity of the water supply of towns, is clear from the prominence which this subject has attained throughout the civilized world during the past few years. In the present paper, it will be my purpose to contrast the nature of the water employed in Calcutta in former years (before the introduction of the present hydrant water) with the supply as it has been since the introduction of the Hooghly water, which is collected and filtered at Pultah, and then distributed by the hydrants, etc. It will be my endeavour to show that the old supply was deficient in quantity, and filthy and abominable in quality, whilst the present supply, though perhaps not so abundant in quantity as it ought to be, is in quality very good and wholesome.

Before proceeding to the discussion of the question of the two supplies, it will perhaps be well to consider what is the general history of natural waters, as this will enable us to understand some of the actual results which have been found by analysis.

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The primary form of natural water is rain, and although at first sight it might appear that rain water should be very pure, yet it has been clearly shown* that it is very seldom that such is the case, and that rain water almost always contains, as impurities, small quantities of organic matter, ammonia, and ammonium salts, derived from the atmosphere. In large towns especially, the rain water is so impure, that it cannot be considered a safe water supply for drinking and other domestic purposes. On reaching the ground the water becomes charged to a greater or less extent with the various soluble constituents of the soil, and with any other matters which may have accumulated in it. If it falls on land either cultivated or uncultivated, it rapidly drains off, and finds its way into streams and rivers, which in the earlier parts of their course certainly, will be tolerably free from organic impurity, except that derived from any manure, etc. which may have been on the land. Unless the river water is subsequently rendered impure by the admission of sewage from towns, villages, etc., or by the admission of manufacturing refuse, it will form, generally speaking, a comparatively pure and wholesome supply of water. In some cases, however, such water is used by the inhabitants of towns on its banks, and is after use returned to the river in the form of sewage, which will be charged with impurity derived from animal excreta, household and manufacturing refuse, soap, and other filth. Water contaminated in such a way is clearly unfit for domestic use. After returning to the stream it will perhaps in its course towards the sea become partially purified by slow oxidation of the organic matter and by the absorbent action of vegetation, but as will be subsequently shown this process of purification is an extremely slow one.

In the case of rain water falling in towns such as Calcutta, it will, as pointed out previously, be impure from the presence of organic matter, ammonia, etc.; of this impure water a considerable proportion of it as before shewn will find its way into the river or into smaller streams communicating with it, but another portion will be collected in the tanks, which are dug for this purpose, and a third portion after percolating through the soil will find its way into numerous shallow wells. These tanks and shallow wells may therefore be considered as being merely pits for the accumulation of drainage from the immediately surrounding soil. In the case of Calcutta the town is densely populated, and as the manners and customs of the native inhabitants are in many respects very primitive, the soil must be inevitably charged with excretal and other refuse, so that the water when it reaches the tank or well, will be largely contaminated with the impurities derived from these sources. In the absence of any system of drainage, as was the case in Calcutta some years ago, such tank or well water could only

* Angus Smith on Air and Rain.

after use be thrown on the surface of the ground, or into the nearest ditch, from which it would either run or percolate into the tank or well a second time, and would naturally be in a still more impure condition. Such would appear to be the natural conclusions as to supplies of water derived from rivers, and from tanks and shallow wells in towns, and it will be subsequently seen that the quality of the Hooghly river water, and of the water of the tanks and wells within Calcutta, as deduced from numerous analyses fully bears out the above suggestions.

In speaking of the former supply of water to Calcutta, I have assumed that it was confined to the various tanks and wells distributed throughout the town; for though there is no doubt that the river water was used considerably by the inhabitants who lived near the banks of the river, yet the greater number of the inhabitants living as they did at a distance from the river, must have depended for their supply of household water on the tanks and wells nearest to them. The modern water supply of Calcutta which we have to consider is of course the Hooghly water collected at Pultah and, after filtration, etc., distributed through the ordinary mains.

For the purposes of this paper I have not thought it necessary to analyze all the tank and well waters in the town, which amount to many hundreds, but as I have examined 200 samples, some from the crowded districts of the northern part of the town, and some from the open maidan, I think a fair conclusion can be derived from them. I have also to mention, that a very large number of the well and tank waters which I have analyzed, have been noticeable for their bad quality, and for having apparently given rise to disease of one kind or another to the persons who were living in the neighbourhood. Therefore the numbers usually obtained represent the bad rather than the good waters of the old supply. I should however wish to point out, that there is every probability, that the water in the tanks and wells now, is of a much better quality then formerly it was, for by the present system of drainage and conservancy, a vast amount of excreta and filth of all kinds is removed from the town, which in former days must have remained to choke up the soil, and to render the tank and well water very much more impure than at present.

I will attempt first to shew, that, when the inhabitants of this town depended for their water supply on the tanks and wells, the quantity was decidedly insufficient during at least one half of the year.

With regard to the necessity of a sufficient supply of water being given to a town for domestic and sanitary purposes, a well known author on Hygiene, writes—*

" It was there shown that want of water leads to impurities of all kinds; the person and clothes are not washed, or are washed repeatedly in

* Parkes' Hygiene, 5th edition, p. 37.

the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself.

"The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and ophthalmia in some cases, are thus propagated. It has also appeared to me that the remarkable cessation of spotted typhus among the civilized and cleanly nations, is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

"The deficiency of water leading to insufficient cleansing of sewers has a great effect on the spread of typhoid fever and of choleraic diarrhœa; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain."

In judging of the quantity of water necessary to be supplied to a town, notice must be taken of the purposes for which the water is used. These we may roughly summarise by saying that water is required for drinking, cooking and the washing of persons, clothes, utensils and houses, for the flushing and cleansing of sewers and drains and for the watering of streets, for the drinking and washing of animals, the cleansing of carriages and stables, for trade purposes, etc.

From European statistics given by the authority just quoted, it would appear to be generally admitted, that a fair allowance of water for the purposes above enumerated is 25 gallons per head of population per day. Thus taking some of the largest towns in England and including Paris, each inhabitant receives $27\frac{1}{2}$ gallons per day; the average daily supply of 14 English towns of second rate magnitude was 24 gallons per head, and that of 72 English and Scotch towns was found to be 26·7 gallons per inhabitant.

Let us now see the amount of water available in Calcutta during certain portions of the year when the old supply was depended upon. The tanks and wells in any town can of course only receive their supply of water from rain, and the rainfall of Calcutta is so unequally distributed, that almost three quarters of the whole fall takes place within 4 months of the year, whilst within 6 months, ten-elevenths of the rain falls. Thus the annual rainfall of Calcutta from 49 years' observation, has been found to be 65·85 inches, and during the months from November to April inclusive, only 6·03 inches fall on the average.

If we exclude from our calculation the months of heaviest rainfall, when the water would almost entirely run off into the river and be lost, and assuming for a moment that during these six months from November to April, the whole of the water which fell could be collected and stored for use ; then knowing that, according to the last Calcutta Census, the density of the population was 109 persons per acre, it is easy to calculate that each person could receive but 6·8 gallons of *fresh* water daily. In all probability, however, not one-fifth of the rainfall finds its way into these tanks and wells, and this would leave the inhabitants less than $1\frac{1}{2}$ gallons of *fresh* water per day during the hot season of the year. In the Coomartolle Section of the town where the density of the population is 214 per acre, this supply must be reduced to one half or to about three quarters of a gallon of *fresh* water per day.

If even we were to assume, that it was possible to store up the water which fell during the rains, for use during the dry season of the year, and granting as before that one fifth found its way into the tanks and wells, even then each inhabitant of the town could not have had more than 6 or 7 gallons of fresh water daily, and an inhabitant of some parts of the northern division, could not have had more than 3 or 4 gallons.

The conclusion seems to me to be inevitable, that at the time when Calcutta depended for its water supply on its tanks and wells, the inhabitants must have used the same water over and over again though of course without knowing it, not only for such purposes as bathing, washing clothes etc., but probably also for cooking and even for drinking, and it would also appear that there could have been absolutely no water for necessary sanitary measures.

That Calcutta, under these circumstances, should have had a high rate of mortality is scarcely surprising.

I will now endeavour to show that the quality of the old water supply was even less satisfactory than its quantity, and that in a large number of instances of tank and well water, if not in the majority of cases, the water was, and still is, simply sewage, sometimes concentrated, sometimes dilute.

That impure water may be the source of disease is, I believe, now admitted on all hands, and if confirmation were required, abundant evidence to this effect is given in the various reports of the Rivers Pollution Commissioners in England. The researches too of Chauveau, Burdon, Sanderson, Klein and others scarcely leave room for doubt that the specific poisons of the so-called zymotic diseases consist of organized and living matter ; and it is now certain that water is the medium through which some at least of these diseases are propagated. There does not appear indeed to be any doubt whatever that such diseases as cholera, typhoid fever, dysentery and diarrhœa may be produced by drinking impure or infected water. An excellent and most conclusive instance of the propagation of typhoid fever by water from one infected case near Basel in Switzerland is admirably described by Dr. Hägler, and is given in the sixth report of the Commissioners above referred to.

It is then evident that, in the analysis of water, the point to be aimed at would be, the detection of the presence of those impurities whether they be of the nature of germs or not, which would give rise to the diseases just mentioned, but unfortunately in the present state of science, we are quite unable even to say with any certainty whether such germs of disease will ever be isolated, and it is therefore clearly out of the power of the chemist to detect their presence in any sample of water. Failing therefore in this endeavour, the chemical analyst has to rest content with the detection and estimation of other substances, such as organic nitrogenous matter etc., which cannot be present in water, unless it has previously been in contact with the various forms of impurity, which we denominate sewage; and if such bodies are present in quantity, it is fair to infer that these germs or other bodies which produce the zymotic diseases, and which are undoubtedly present very frequently in sewage, may also be present in the sample of water. It has also been clearly shown, that in many instances water which is impregnated with animal or vegetable organic matter, even assuming any specific poison to be absent, will give rise to various unpleasant symptoms, such as diarrhœa, etc. It is therefore quite permissible and necessary to condemn any sample of water which is to be used as a potable or domestic supply, if it contains any quantity of organic matter, more especially if the organic matter be of animal origin.

The methods of water analysis have been improved very greatly during the past fifteen years, but even now there is a very warm discussion being carried on as to the respective merits of at least three distinct processes, and opinions differ materially as to which method gives most accurate and reliable results. The two methods for the determination of the amount of organic matter present in water, which have met with the greatest amount of support, are those of Professors Wanklyn and Frankland.

The method proposed by Prof. Wanklyn, which consists in the conversion of the nitrogenous organic matter into ammonia by boiling with an alkaline solution of potassium permanganate, has the immense advantage of being quickly performed with tolerably simple apparatus, and a whole water analysis by this method does not occupy more than a few hours. Against this method there is the well recognized fact, that it sometimes fails to detect and estimate the whole of the nitrogenous organic matter present in the water. It is therefore possible that a water may escape the condemnation which it deserves, but I believe it is generally accepted that a water which is condemned by this process must be really of very bad quality.

The method of analysis which was introduced by Dr. Frankland is an extremely elaborate one, and requires the use of very delicate and expensive apparatus. The greatest drawback to this process is however, the amount of work and time which is required for it, as a satisfactory analysis by it cannot be performed in less than 4 or 5 days. On the other hand the results obtained by Frankland's process are eminently trustworthy, and the character of a water is determined by it with great precision.

As I have been obliged to perform the work of analysis of the tank and well waters of Calcutta during the spare time from my current duties, and as some two hundred analyses had to be made by my own hands, it was clearly impossible for me to use Frankland's more accurate process, and I was compelled rather against my own notions of scientific accuracy to work with Wanklyn's process, which as I have pointed out is not so trustworthy as the other. In addition to this reason, I found that my predecessor in the office of Analyst to the Corporation had been in the habit of testing the Calcutta hydrant water by Wanklyn's process. As I had to carry on this method of analysis on behalf of the Corporation, this therefore formed a very intelligible standard of comparison for my work with the former water supply of Calcutta. In addition however to these analyses of the hydrant water, as will be seen subsequently, I have carried out for the last four years monthly analyses of the hydrant water by Frankland's process, and it is upon these numbers that I shall base my conclusions as to the character and quality of the present water supply.

In Wanklyn's process there are two principal determinations. The first is the estimation of the free ammonia present in the water, and of the albuminoid ammonia obtained by distillation with alkaline potassium permanganate. In India, I have frequently combined these two processes, and the ammonia from both is called the "Total Ammonia." The reason why these two processes have been combined is, that in almost every case when I have tested the *potable* waters of India for free ammonia, I have found it to be almost entirely absent. The fact appears to be, that at the very high temperature which here obtains, the ammonia oxidizes with such extreme rapidity, that if any free ammonia were present at the collection of the water, it would become partially or wholly converted into inorganic nitrogenous matters before the analysis could be performed, or, if the whole of the free ammonia were not thus oxidized, the changes which go on from day to day are so great, that for any true comparison in respect of this constituent between the samples of water analyzed, it would be necessary to analyze them at definite intervals after collection. The "total ammonia" then, which is spoken of subsequently, is the free ammonia present, if any, added to the ammonia produced from the nitrogenous organic matter by the oxidizing action of alkaline potassium permanganate. As pointed out before, it frequently happens that the whole of the nitrogenous organic matter present in the water is not decomposed, and therefore the numbers obtained always represent the minimum amount of impurity which can be present in the water.

Professor Wanklyn says with regard to this method of analysis, that by the aid of the ammonia process, we are now able to divide potable waters into three broad classes :

(1) Waters which are of "extraordinary organic purity," *i. e.*, those which are almost free from any nitrogenous organic matter, and which contain less than 0·05 parts of albuminoid (or total) ammonia per million of water.

(2) "Safe waters," which are devoid of any excess of nitrogenous organic impurity, and which contain from 0·05 to 0·10 parts per million of albuminoid ammonia.

(3) Waters which are "dirty," *i. e.* charged with an abnormal quantity of organic matter, and which contain more than 0·10 parts of albuminoid ammonia per million of water.

The second important consideration is the determination of the amount of chlorine present in the water. Chlorine occurs in potable water in combination with several metals (as chlorides), such as sodium, magnesium, calcium and possibly potassium. The amount of chlorides or of chlorine present in drinking water is in itself of little importance, for as most people are aware, common table salt is simply sodium chloride, and this substance is a necessary ingredient of our food. The water analyst determines the amount of chlorine present in water because the presence of this substance in water is in most instances a clear indication of contamination by sewage in some form or another.

It will be understood how this is the case when we consider that rain water, which is the source of all water supplies when collected in the open country and at inland stations is practically free from chlorine. Drinking water also which is uncontaminated by sewage is comparatively free from this substance, but sewage and urine,* are highly charged with chlorides, of which common salt is probably in largest quantity. If then a given sample of water contains no chlorine or very little, it *cannot* have been in contact with sewage, but if any considerable amount is present in a water, which is known not to have come from a tidal river or from any geological formation where deposits of salt are found, such a water would be viewed with the gravest suspicion, and if this were supported by other evidence, the water would at once be condemned. Unpolluted river and spring waters usually contain less than ten parts of chlorine per million of water, average town sewage in England about one hundred and ten parts ; shallow well water may contain any quantity from a mere trace up to 500 parts or even more. The amount of chlorides is scarcely affected by any degree of filtration through soil ; thus the effluent water from land irrigated with sewage contains the same proportion of chlorine

* Human urine contains about 5000 parts of chlorine per million of liquid.

as the sewage, unless it has been diluted by subsoil water or concentrated by evaporation.

As an illustration of the quantities of total ammonia and of chlorine as chlorides found in samples of *good* or *fairly good* drinking water, I may quote some numbers taken partly from Prof. Wanklyn's work on water analysis, and partly from other sources such as the Rivers Pollution Commissioners' Reports. The numbers given in the following table show the number of parts of total ammonia and of chlorine in every million parts of the water, and the samples of water it will be seen are selected from a variety of sources, such as lakes, rivers, wells, springs, &c.

Description of Water.	Total Ammonia parts per million of water.	Chlorine parts per million of water.
London water, Kent Company, ...	0·03	23·5
" " New River Company, ...	0·08	15·7
Glasgow water from Loch Katrine, ...	0·08	7·6
Edinburgh town water, ...	0·07	14·3
Manchester town water, ...	0·07	9·0
Chester (Dee) town water, ...	0·07	5·0
Oxton (Birkenhead) town water, ...	0·02	
Guildford water, ...	0·01	12·6
Caterham water from deep spring, ...	0·04	15·5
Deep spring at Dorking, ...	0·01	
Deep Well at Chatham, ...	0·06	

As an additional comparison of the quantities of "Total Ammonia" and of Chlorine, which a good potable water should yield, I will quote the amounts of these substances which have been obtained during the last four years from analyses of the Calcutta Hydrant water made twice in each week. In the following table there are given the average results obtained for each of the last four years, as well as the general average for the whole of this period.

Calcutta Hydrant Water.

	No. of days of Analysis.	No. of days when transparent and colorless.*	No. of days when not perfectly filtered.	Total ammonia in parts per million..	Chlorine in parts per million.
Average 1876, ...	155	137	18	0·037	10·65
" 1877, ...	104	72	32	0·046	10·40
" 1878, ...	103	75	28	0·034	8·37
" 1879, ...	103	91	12	0·035	8·50
Sums, ...	465	375	90	0·152	37·92
Average, ...	116	94	22	0·038	9·48

* When examined by transmitted light in a tube three feet in length.

In passing I may here remark, that a comparison of these numbers with those of the previous table, shows that the present water supply of Calcutta is really of excellent quality, and that very few of the *good* waters selected from those given in the works alluded to, are as pure as our hydrant water. That the purity of the hydrant water as determined by this process of analysis is not merely exceptional, is clear from the close agreement of the results of each year with the average of the four years. It will also be noticed that the hydrant water will fall in class one of Prof. Wanklyn's classification, as being a water of extraordinary organic purity.

On the other hand as examples of waters which are considered in England to be exceptionally bad, and which are at once condemned as sources of water for domestic purposes, and as examples of the results obtained from sewage, I may quote the following from Prof. Wanklyn's work on water analysis.

Description of Water.	Total ammonia parts per million of water.	Chlorine parts per million of water.
Unfiltered Thames water at Hampton Court, ...	0·32	11·4
,, Thames water at London Bridge, ...	2·11	17·1
Well at Leek Workhouse (Staffordshire), ...	0·36	7·1
Well in Windsor, ...	1·28	80·0
Well in Eton, ...	0·84	80·0
Pump in Drapers Hall, London, ...	6·31	
,, ,, Bishopsgate St., London, ...	7·75	
,, ,, Goodge St., London, ...	......	177·0
,, ,, Oxford Market, ...	......	474·3
Sample of Sewage, ...	17·10	141·4

In addition to these examples I have analysed the Calcutta sewage by the same process. Thus on December 18th, 1877, samples of sewage were collected at each hour from 6 A. M. to 6 P. M. at the Pumping Station, and the amounts of total ammonia obtained from three of the samples showed 84·0, 87·0 and 145·6 parts per million of water. The average amount of chlorine was 170·4 parts in the same volume. This shows a much more concentrated sewage than that analysed by Prof. Wanklyn, but it is fair to state that the three samples of Calcutta sewage were of extreme concentration, and of a most repulsive and disgusting character.

If we take the first two tables above given as representing good drinking waters, and the last as representing sewage, either dilute or concentrated as the case may be, we are now in a position to understand the meaning of the numbers obtained by the analyses of two hundred samples of Calcutta tank and well waters, which are given in the tables below.

I have previously noticed the three standards of purity suggested by Prof. Wanklyn, but as in the case of these Calcutta tank and well waters, we shall be dealing with very impure samples, it will be well to adopt some standards of greater impurity than before given. I think it will be well within the mark to consider, that any sample of water which produces more than 10 parts of total ammonia should be classed as a sewage and not as a water, and that if the amount produced is between 10 and 5 parts, the sample may be called a dilute sewage; from 5 parts to 1 part we have a water considerably contaminated with sewage, and from 1 part down to Prof. Wanklyn's limit of 0·10 parts of total ammonia, we have the class of Dirty Waters, which represent water contaminated more or less with organic or sewage matter. In the same way we may adopt a classification of the amounts of chlorine present, and there is apparently no doubt that a Calcutta tank or well water which contains more than 250 parts of chlorine per million should be classed as a sewage; that a water containing from 250 to 150 parts of chlorine may be looked on as a dilute sewage; that with from 150 to 100 parts of chlorine present we have a water considerably contaminated with sewage; and when from 100 to 50 parts are present a water may be said to be slightly contaminated, whilst if less than 50 parts of chlorine are present, the water may be considered moderately safe.

The first of the two following tables contains the results obtained from the analysis of the tank waters, and the second the numbers obtained from the well waters. The tables contain 9 columns, most of which are explained by their headings. Column 1 gives the date on which the water was analysed, 2 and 3 the locality from which the sample was drawn and the section of the town in which the tank or well is situated. Column 4 gives the reason why my attention was called to the state of the tank or well, and which lead to the water being analysed. Column 5 gives a very brief description of the physical characters of the sample, principally as to colour, smell, presence or absence of solid matters in suspension, presence of animal life etc., and under this head it may be mentioned that as most of the waters were extremely dirty and thick, the examination as to colour was made in a glass cylinder only six inches high standing on a white surface. Columns 6 and 7 give the amounts of total ammonia and of chlorine present in every million parts of water. Column 8 gives the decision as to whether the water was considered fit for potable purposes or whether it was condemned for such uses, and the last column shews whether the tank or well has been subsequently filled up or dewatered.

Most of these results have been submitted to the Health Officer to the Municipality in my capacity of Water Analyst, and it is due to the courtesy of Dr. McLeod that I am able to give the columns 4, 8 and 9.

Tank Waters, 1876.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Amt of Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the Tank.
March. 1	No. 19, Goa Bagan Street, North Tank.	C	For cholera death in neighbourhood.	Yellowish green color, very turbid. Full of life.	18·52	582·00	Condemned.	Filled up.
,,	No. 19, Goa Bagan Street, South Tank.	C	Do.	Yellowish green color, very turbid. Full of life.	26·20	639·00	Do.	
,, 16	Name of locality not clearly ascertained.		Do. and complaint.	Greenish color. Full of animal life.	24·80	568·00	Do.	
,, 24	Nihareeparah.	A	Filthy state.	Green color, unpleasant smell, suspended matter.	18·00	550·25	Do.	
,, 27	Nundoram Sen's Street.	B	Do.	Brown white color. Very turbid, Full of life.	10·00	390·50	Do.	Filled up.
,, 28	Krupanauth's Lane.	B	Do.	Tolerably clear. Full of life.	2·40	443·75	Do.	
,, 29	Boloram Ghose's Street.	A	Do.	Greenish color, very turbid. Full of life.	2·00	514·75	Do.	Filled up.
,, 30	Raja Rajbullub Street.	A	Do.	Rather clear; small floating worms.	2·00	514·75	Do.	Filled up.
April 20.	Bortollah Tank.	C	Cholera death in neighbourhood.	Yellowish white color, turbid, contains animal life.	2·20	255·60	Do.	Filling.
May 2.	7, Grey Street.	C	Filthy state.	Yellowish green color, stinks horribly, full of suspended matter and animal life.	20·00	710·00	Do.	Filled up.
,, 3.	Kerr's Lane.	M	Do.	Green color, stinks horribly, full of sediment, animal life	13·75	319·50	Do.	Do.
,, 9.	141, Dhurrumtollah Street.	K	Do.	Whitish green color, rather strong stink, full of animal life.	9·60	268·25	Do.	Do.
,, 10.	102, Jaun Bazar Street.	N	Do.	Green color, stinks horribly, full of life, animal and vegetable.	9·60	284·00	Do.	
Aug. 15.	Presidency Jail Tank.	Q	Do.	Of greenish color, slightly turbid.	1·30	46·15	Do.	
,,	Alipore Jail Tank.		Do.	Yellowish color, slightly turbid.	0·68	35·50		Filled up.
Sept. 19.	Sookea's St. Thana, North Tank.	D	Do.	Brownish color, contains suspended matter and considerable amount of animal life.	1·62	184·60	Do.	
,,	Sookea's St. Thana, South Tank.	D	Cholera death in neighbourhood.	Almost colorless, contains suspended matter, little if any animal life visible.	·35	142·00	Do.	Filling.
Dec. 16.	Komadan Bagan, Double Tank.	N	Do.	Slight greenish color, faint smell, turbid, full of animal life.	2·40	266·25	Do.	
,,	Tank Haree Tollowa.	N	Do.	Greenish white color, very unpleasant smell, very turbid, full of animal life.	7·65	372·75	Do.	
,, 22.	D Tank Water.			Of a whitish color, turbid, contains animal life, but apparently not in large quantity.	0·60	31·95		

Tank Waters, 1877.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Amt. of Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the Tank.
Jan. 9.	Godai Khansama's Lane, Colinga.	O	Filthy state.	Greenish white color, turbid, and full of animal life.	3·06	156·20	Condemned.	Dewatered.
„ 12.	Gopal Mitter's Tank in Brindabun Mullick's Lane.	D	Cholera death in neighbourhood.	Of a greenish color, turbid, and full of animal life.	2·52	475·70	Do.	
„ 16.	Dhankhit Tank, Colvin's Bustee.	Q	Filthy state.	Of a whitish color, turbid, and full of animal life.	16·00	170·40	Do.	
Feb. 13.	74, Dhurumtollah Street.	B	Complaint of do.	Of a whitish color, and turbid.	14·80	195·25	Do.	
„ 23.	Tolley's Nullah.	R	Filthy state.	Of a whitish color, and turbid.	·10	71·00		
„	Hastings Bridge, (foot of).	R	Do.	Of a whitish color, and turbid.	·10	65·67		
Mar. 6.	Tolley's Nullah taken between High water and mid ebb-tide.	R	Do.	Of a whitish color, and turbid.	·08	22·36		
„ 12.	31, Neogipuker East Lane.	N	Cholera death in neighbourhood.	Green color, stinks horribly, turbid, full of green suspended matter.	8·00	230·75	Do.	No. 30, Filledup.
„ 13.	42, Hareepara Lane.	N	Do.	Whitish brown color, smells badly, very turbid.	61·28	355·00	Do.	Filledup.
„ 14.	62, Lower Circular Road.	N	Do.	Green color, suspended matter, stinks, turbid, full of animal life.	47·04	230·75	Do.	Do.
„ 15.	32, Neogipuker East Lane.	N	Do.	Green color, suspended matter, stinks, turbid.	24·00	142·00	Do.	No. 33, Filledup.
„ 16.	30, Hareepara Lane.	N	Filthy state.	Brownish color, faint smell, slightly turbid.	24·00	230·75	Do.	Filledup.
„ 17.	16, Neogipuker W. Lane.	N	Do.	Greenish white color, faint odour, very turbid, green suspended matter.	120·00	337·25	Do.	
„ 18.	19, Okur Dutt's Lane.	K	Cholera death in neighbourhood.	Greenish white color, faint smell, turbid.	12·84	159·75	Do.	Filledup.
„ 19.	18, Holodhur Buddan's Lane.	K	Filthy state.	Brown almost black color, stinks, very turbid, full suspended matter.	40·80	319·50	Do.	
„ 20.	15, Takoor Doss Paulit's L.	K	Do.	Brownish white color, stinks, excessively turbid.	16·00	248·50	Do.	

Tank Waters, 1877—*Continued.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Amt. of Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the Tank.
Mar 20.	10, Okur Dutt's Lane.	K	For Cholera death in neighbourhood.	Brownish or blackish white color, stinks, excessively turbid.	24·00	266·25	Condemned.	Filled up.
„	15, Ooriahpara Lane.	K	Do.	Do. Do. Do.	60·00	355·00	Do.	
„ 21.	16, Cornwallis Street.	D	Do.	Greenish white color, stinks, turbid.	16·00	159·75	Do.	
„	22, Sunkur Ghose's Lane.	D	Do.	Brownish white color, smells, slightly turbid.	16·00	284·00	Do.	
„ 22.	36, Sankaritollah Lane.	K	Do.	Brownish white color, stinks, excessively turbid.	16·16	408·25	Do.	
„	103 & 104, Serpentine Lane.	K	Do.	Greenish brown, stinks horribly, excessively turbid.	240·00	319·50	Do.	
„ 23.	2 & 3, Holodhur Buddan's Lane.	K	Do.	Brownish white color, slightly turbid, little suspended matter.	8·40	230·75	Do.	
„	21, Jalliapara Lane.	K	Do.	Almost transparent, little suspended matter.	200·00	159·75	Do.	
„ 25.	8, Ukur Dutt's Lane.	K	Do.	Brownish color, smells, turbid.	1·80	479·25	Do.	
„	8, Kisto Laha's Lane.	K	Complaint.	Stinks horribly, excessively turbid, full of bright green suspended matter.	26·40	426·00	Do.	
„ 26.	9, Sepentine Lane.	K	Cholera death.	Whitish green color, stinks, very turbid.	8·00	355·00	Do.	
„	90, Chitpore Road.	G	On H. O.'s report.	Yellowish brown color, no smell, slightly turbid with suspended matter.	0·48	117·00	Do.	
„ 28.	7, Grey Street.	C	For Cholera death in neighbourhood.	Yellowish brown color, smells, opalescent, little suspended matter.	16·00	461·50	Do.	Filled up.
„	115, Upper Chitpore Road.	G	Do.	Brownish color, smells, opalescent, suspended and animal matter.	8·00	266·25	Do.	
„ 29.	22, Musjeedbarree Street.	C	Do.	Bright green color, stinks horribly, extremely opalescent, suspended matter.	19·84	390·50	Do.	
„ 30.	63, Hurry Ghose's Street.	C	Do.	Brownish almost black color, stinks, suspended matter.	12·60	248·50	Do.	
„	5, Fukeer Chand Chatterjee's Street.	C	Do.	Brown color, stinks horribly, extremely opalescent, much suspended matter.	28·56	585·75	Do.	
„ 31.	27, Taruk Chatterjee's Lane.	C	Do.	Brown color, smells, opalescent, suspended matter.	20·00	301·75	Do.	
„	31, Durjeeparah Street.	C	Do.	Yellow color, smells, suspended matter.	8·00	390·50	Do.	

April 10.	28, Goa Bagan W. Goalla-para.	C	Complaint of raging cholera.	Greenish black color, stinks, opalescent, full of suspended matter.	6·40	426·00	Condemned.	
,,	16, Do. Do.	C	Do.	Bright green color, stinks, excessively opalescent, full of suspended matter.	20·96	337·25	Do.	
,, 12.	Double Tank, Komadar Bagan, Joratolla.	O	Foul state.	Greenish white color, stinks, with much suspended matter and animal matter.	3·90	177·50	Do.	Nos 19 4 and 96 filled up.
,,	99, Jaun Bazar Street.	N	Do.	Yellowish color, unpleasant smell, slightly turbid, suspended matter & also animal life.	7·20	124·25	Do.	
,, 16.	Tank A.		Do.	Almost colorless and smells unpleasantly; much suspended matter.	Lost.	74·50		
,,	Tank B.		Do.	Stinks of sulphuretted hydrogen, becomes opalescent on exposure, much suspended matter.	3·20	81·60	Do.	
Aug. 7.	75 & 76, South Colinga St.	O	Foul state.	Yellow color, smells slightly, contains suspended matter.	2·36	159·75	Do.	No. 74, dewatered
,, 10.	24, Baranosee Ghose's St., Singhee Bagan.	F	Cholera death in neighbourhood.	Almost colorless, faint unpleasant smell, and suspended matter, much animal life.	2·68	142·00	Do.	Filled up.
,, 28.	29, Neogipukur East Lane.	N	Do.	Water of a yellowish color, faint unpleasant smell, much animal life.	2·64	276·90	Do.	
Oct. 9.	10 & 12, Elliot's Road.	O	Do.	Yellowish color, stinks, opalescent, contains animal life.	4·29	71·00	Do.	Filled up.
,, 10.	6, Hill's Lane.	O	Complaint.	Yellowish color, smells slightly, slightly opalescent, animal life.	3·95	142·00	Do.	
,, 26.	62, Machooa Bazar Street.	I	Cholera death in neighbourhood.	Greenish white color, stinks badly, full of suspended matter and animal matter.	4·40	213·00	Do.	Filled up.
,, 27.	44, Musjeedbarry Street.	C	Filthy state.	Yellowish green color, stinks, some suspended matter, animal life.	2·59	266·25	Do.	
,, 30.	38, Nilmoney Mitter's St.	C	Complaint.	Greenish brown color, stinks, suspended matter, animal life.	9·00	301·75	Do.	Filled up.
Nov. 2.	7, Sookea's St., Bye-Lane.	D	Cholera death in neighbourhood.	Yellowish green color, slight smell, slightly opalescent, small quantity suspended matter, full of animal life.	3·40	185 25	Do.	
,, 3.	11, Carey's Church Lane.	I	On Tank Committee's report.	Brownish white color, unpleasant smell, slightly opalescent, small quantity suspended matter, full of animal life.	12·00	185·25	Do.	

Tank Waters, 1877—*Concluded.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Amt. of Cholerine parts per million.	Whether condemned for domestic purposes or not.	What was done to the Tank.
Nov. 8.	Colvin Bustee Tank.	Q	Cholera death in neighbourhood.	Greenish white color, stinks, opalescent, full of green suspended matter and animal life.	13·00	195·25	Condemned.	
„ 10.	9, Shampuker Street.	A	Do.	Greenish color, slight smell, slightly opalescent, full of green suspended matter and animal life.	9·84	181·05	Do.	
„ 11.	85, Machooa Bazar Street.	D	Do.	Yellowish brown color, slight smell, opalescent, full animal life.	11·30	159·75	Do.	
„ 12.	6, Emambaug 2nd Lane.	J	Complaint.	Green color, faint smell, much suspended matter, and animal life.	3·00	113·60	Do.	
„ 13.	75, Jaun Bazar Street.	N	Cholera in neighbourhood.	Greenish yellow color, stinks, rather opalescent, small quantity of suspended matter, full of animal life.	2·76	202·35	Do.	
Dec. 10.	46, Kally Prosad Dutt's St.	C	Do.	Dark green brown color, on being kept a few days stinks horribly, full of green suspended matter, and animal life.	28·56	205·90	Do.	No. 54, Filled up.
„ 11.	104, Upper Circular Road.	C	Do.	Whitish brown color, when kept a few days has a very bad smell, full of green suspended matter, contains animal life.	23·52	262·70	Do.	
„	12, Nuzur Nuzubullah's Lane.	O	On the report of Tank Committee.	Greenish white color, has unpleasant smell, moderate amount of suspended matter, much animal life.	8·40	181·05	Do.	
„ 18.	18, Hareepara Lane, and 15, Neogipuker West Lane.	N	Filthy state.	Green color, stinks most horribly, much suspended matter, full of animal life.	11·16	244·95	Do.	Filled up.

Tank Waters, 1878.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the Tank.
Jan. 2.	54, Raja Rajbullub Street.	A	Cholera death in neighbourhood.	Deep yellowish color, very unpleasant smell, full of suspended matter and animal life.	21·30	475·70	Condemned.	
„ 7.	3, Fukeer Chand Mitter's Lane.	D	Do.	Yellowish green color, unpleasant smell, little suspended matter, contains animal life.	3·46	92·30	Do.	
„ 8.	129, Cornwallis Street.	C	Do.	Bright green color, stinks, much suspended matter, much animal life.	21·06	280·45	Do.	No. 30, Filled up.
„ 9.	4, Fukeer Chand Mitter's Lane.	D	Do.	Water yellowish color, some suspended matter.	12·00	149·10	Do.	
„ 10.	21, Do. Do. Do.	D	Do.	Yellowish green color, unpleasant smell, slightly opalescent, little suspended matter, animal life.	4·70	127·80	Do.	
„ 19.	81, Shampookur Street.	A	Do.	Yellow color, slight smell, little suspended matter, much animal life.	2·72	142·00	Do.	
„ 30.	27, Noyau Chunder Dutt's Lane.	C	Do.	Yellow, stinks, small quantity suspended matter, no visible animal life.	1·47	124·25	Do.	
„	Karbala tank water.	C	Do.	Has a brown color, unpleasant smell, contains suspended matter, animal life.	1·49	276·90	Do.	
Feb. 27.	162, Bow Bazar.	I	Do.	Yellow brown color, stinks, opalescent, much suspended matter, no life.	40·66	266·25	Do.	
„	1, Nemoo Gosain's Lane.	B	Do.	Brown color, stinks badly of sulphuretted hydrogen, opalescent, much suspended matter, animal life.	23·20	479·25	Do.	
Mar. 5.	Jinghu Bagan.	J	Do.	Green yellow color, stinks horribly of sulphuretted hydrogen, opalescent, much suspended matter.	11·50	408·25	Do.	
„ 8.	2, Manicktollah Street.	J	Do.	Brownish color, stinks, very opalescent, much suspended matter, animal life.	38·74	461·50	Do.	

Tank Waters, 1878—*Continued.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the tank.
Mar. 11.	222, Cornwallis Street.	J	Cholera death in neighbourhood.	Greenish color, stinks, very opalescent, animal life.	3·52	248·50	Do.	
"	26, Prossunno Coomar Tagore's Street.	E	Do.	Bright green color, stinks horribly, very opalescent, full of green suspended matter, full of animal life.	17·00	319·50	Do.	
" 12.	22, Horo Lall Mitter's Street.	A	Do.	Brownish color, bad smell, very opalescent, small quantity suspended matter, animal life.	7·68	301·75	Do.	
" 13.	45, Shampookur Lane.	A	Complaint.	Yellowish white color, stinks, large quantity suspended matter, visible animal life.	3·02	230·75	Do.	
"	54, Old Boytuckhanah Bazar Street.	I	Cholera death in neighbourhood.	Brown color, stinks, much suspended matter, much animal life.	42·66	355·00	Do.	
" 26.	Mirzapore Public Tank.	I	Do.	Greenish color, faint smell, small quantity suspended matter, animal life.	1·31	102·95	Do.	
"	Badoorbagan Tank, 83, Upper Circular Road.	D	Do.	Greenish color, stinks, green suspended matter in large quantity, animal matter in quantity.	2·16	220·10	Do.	
April 27.	Dhurumtollah Public Tank.	M			0·80	24·80		
May 10.	Wellesley Street.	M		Yellow color, slight smell, small quantity suspended matter.	0·34	147·68		
"	Palmer's Bridge.	R		Yellowish brown, slight smell of sulphuretted hydrogen, much suspended matter.	0·17	2378·5	Do.	

Tank Waters, 1879.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million of water.	Chlorine parts per million of water.	Whether condemned for domestic purposes or not.	What was done to the tank.
Jan. 22.	82, Upper Circular Road.	N	Cholera death in neighbourhood.	Blackish green color, very bad smell, suspended matter, contains animal life.	2·68	248·50	Condemned.	
,, 22.	83, Upper Circular Road.	N	Do.	Yellow color, stinks badly, much suspended matter, contains animal life.	9·00	213·00	Do.	
June 20.	Rawdon Street.	Q		Yellowish color, slight odour, small quantity of suspended matter, animal life in small quantity.	4·20	269·80	Do.	
July 4.	36, Goorooprosad Chaudry's Lane.	D	Do.	Blackish color, stinks abominably, much suspended matter.	1·98	209·45	Do.	
,, 5.	22, Durga Churn Mukerjea's Street.	A	Do.	Brownish color, stinks badly, much suspended matter.	3·72	213·00	Do.	
,, 7.	4, Brindabun Mullick's Lane.	D	Do.	Brownish color, bad smell, opalescent, small quantity of suspended matter.	7·20	223·65	Do.	
Oct. 10.	5, Peary Mohun Paul's Lane.	H	Complaint.	Brownish black color, unpleasant smell, very opalescent, large quantity of suspended matter.	92·40	177·50	Do.	
,, 11.	10 and 11, Jorapukor Lane.	F	Cholera.	Blackish brown color, stinks badly, very opalescent, large quantity of suspended matter.	77·60	177·50	Do.	
,, 14.	160, Gokul Mitter's Lane, Baug Bazar.	A	Complaint.	Brown color, stinks abominably, very opalescent, large quantity of suspended matter.	11·52	248·50	Do.	
				1880.				
Jan. 24.	No. 19, Goa Bagan Street.	C	Cholera.	Grey color, slight odour, much suspended matter, much animal life.	13·86	319·50	Do.	Filled up.

Tank Waters, 1880—*Continued.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million of water.	Chlorine parts per million of water.	Whether condemned for domestic purposes or not.	What was done to the tank.
Jan. 24.	32, Elliott's Road.	O	Prevalence of Swelling fever.	Grey color, unpleasant odour, much suspended matter, much animal life.	15·20	195·25	Condemned.	
,, 26.	31, Elliott's Road.	O	Do.	Green color, slight odour, much green suspended matter, animal life.	4·00	159·75	Do.	
,, 28.	35, Elliott's Road.	O	Do.	Green color, stinks abominably, much suspended matter, animal life.	6·00	142·00	Do.	
,, 29.	11, Mohendra Gossain's Lane.	F	Complaint.	Bright yellow color, unpleasant smell, suspended matter, much animal life.	23·20	337·25	Do.	
,, 30.	Radhanath Bose's Lane.	C	Do.	Green color, unpleasant smell, suspended matter, much animal life.	6·30	355·00	Do.	
May 29.	31, Bachoo Chatterjea's Street.	D	Do.	Green color, stinks badly, very turbid, suspended matter, animal life.	8·00	401·15	Do.	
July 5.	South of Park Street old Cemetery.			Slight yellow color, no smell, almost clear and transparent, small quantity of animal life.	0·16	255·60		
,, 6.	Birju Tank, south of Cathedral.	Maidan.		Greyish color, no smell, rather turbid, small quantity of animal life.	0·09	13·84		
,, 7.	Elliot's Tank, north of Cathedral.	Maidan.		Slight greyish color, no smell, rather turbid, small quantity of animal life.	0·10	8·16		
,, 8.	General's Tank opposite Bengal Club.	Maidan.		Grey color, no smell, rather turbid, small quantity of animal life.	0·10	32·66		
,, 9.	Monohar Dass's Tank opposite Lindsay Street.	Maidan.		Almost colorless, no smell, almost clear and transparent, very small quantity of animal life.	0·07	16·68		
,, 10.	Tank opposite Esplanade.	Maidan.		Almost colorless, no smell, almost transparent, small quantity of animal life.	0·11	24·14		

Well Waters, 1877.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Amt. of Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the well.
May 8.	5, Jorabagan.	E	Cholera death in neighbourhood.	Greenish black color, stinks horribly, slightly opalescent, full of suspended matter.	1·68	177·50	Condemned.	
„ 9.	1, Horo Lall Doss's Lane.	E	Filthy state.	Slight brownish color, no smell, little suspended matter.	0·80	248·50	Do.	
„ 10.	16, Burrabazar Moydaputty.	G	Do.	Almost colorless, no suspended matter.	0·40	213·00	Do.	
„ 11.	Jaunbazar Bustee.	M		Yellowish color, no smell, traces of suspended matter.	8·20	514·75	Do.	
„ 12.	24, Jorabagan Street.	E	Filthy state.	Almost colorless, faint smell, small amount of suspended matter.	0·62	621·25	Do.	
„ 13.	6, Jorabagan Street.	E	Do.	Brownish color, faint smell, small amount of suspended matter.	0·50	248·50	Do.	
„ 14.	7, Horo Lall Doss's Bustee.	E	Do.	Brownish color, nasty smell, opalescent, suspended matter.	1·76	142·00	Do.	
„ 15.	9, Shama Bye's Gully.	E	Do.	Slight yellowish color, faint smell, small amount of suspended matter.	0·90	426·00	Do.	
„ 16.	30, Burtollah Street.	E	Do.	Almost colorless, faint smell, small amount of suspended matter.	0·50	39·50		
„ 17.	9, Burrabazar Baneaputty.	G	Do.	Brownish color, faint smell, suspended matter.	0·40	177·50	Do.	
„	145, „ Hookaputty.	G		Yellowish color, faint smell, much suspended matter.	0·30	710·00	Do.	
„ 18.	3, Hanspookur Gully.	E	Filthy state.	Strong yellowish brown color, faint smell, much suspended matter.	4·15	307·70	Do.	
„ 19.	159, Machooa Bazar Street.	E		Yellowish color, faint unpleasant smell, little suspended matter.	2·40	390·50	Do.	
Aug. 10.	145, Burra Bazar.	G	Filthy state.	Almost colorless, faint unpleasant smell, suspended matter.	3·68	791·65	Do.	

Well Waters, 1877—*Continued.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Amt. of Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the well.
Aug. 10.	24, Jorabagan Street.	E	Cholera death in neighbourhood.	Yellowish green color, faint unpleasant smell, suspended matter, animal life distinct.	2·84	265·25	Condemned.	
„ 11.	3, Hanspookur Lane.	E		Almost colorless, faint smell, small quantity suspended matter.	1·42	390·50	Do.	
„ 12.	6, Jorabagan Street.	E	Cholera death.	Yellowish color, faint unpleasant smell, small quantity suspended matter, distinct animal life.	3·76	159·75	Do.	
„ 13.	30, Burtolah Street.	E		Colorless, faint unpleasant smell, large quantity of suspended matter, distinct animal life.	2·73	319·50	Do.	
„ 14.	9, Shama Bay's Lane.	E		Almost colorless, faint unpleasant smell, small quantity suspended matter.	2·64	408·50	Do.	
„ 15.	24, Bustee Joraban Street.	E		Brown color, stinks badly, very opalescent, much suspended matter, distinct animal life.	17·40	159·75	Do.	
„ 16.	1, Horo Lall Doss's Lane.	E		Almost colorless, faint smell, small quantity of suspended matter.	3·95	177·50	Do.	
„ 17.	16, Burra Bazar Moydaputty.	G		Colorless, faint unpleasant smell, little suspended matter.	2·83	177·50	Do.	
„ 18.	5, Jorabagan Street.	E	Cholera death.	Whitish yellow color, smells unpleasantly, opalescent, suspended matter, and traces of animal life.	15·80	88·75	Do,	
„ 19.	9, Burrabazar Baneaputty.	G		Almost colorless, faint unpleasant smell, suspended matter, animal life.	3·28	195·25	Do.	
„ 20.	Bustee Horo Lall Doss's Lane.	E		Yellow color, decided unpleasant smell, suspended matter.	4·32	248·50	Do.	
„ 22.	136, Serpentine Lane.	K		Yellow color, unpleasant smell, little suspended matter, much animal life.	6·40	621·25	Do.	

Well Waters, 1878.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the well.
Jan. 28.	Doorga Churn Mittur's Street.	C	Cholera death in neighbourhood.	Almost colorless, but in long cylinder appears yellowish, faint unpleasant smell, small quantity suspended matter, no animal life perceptible.	1·40	88·75	Condemned.	
„ 30.	13-A, Nattur Bagan.	B	Do.	Almost black, unpleasant smell, excessively turbid, animal life.	51·50	841·35	Do.	
Feb. 7.	13-B, Nattur Bagan.	B	Do.	Slight brownish tinge, slight smell, small quantity suspended matter, no visible animal life.	3·30	639·00	Do.	
„	14, Smith's Lane.	N	Do.	Yellow color, slight smell, some suspended matter, small traces of animal life.	3·30	479·25	Do.	
„	30, Noyau Chaund Dutt's Street.	C	Do.	Yellow color, unpleasant smell, small quantity suspended matter, distinct animal life	1·92	152·65	Do.	
„ 15.	10, Ram Kanto Bose's Lane.	A	Do.	Yellowish color, unpleasant smell, moderate amount suspended matter, no visible animal life.	12·80	582·20	Do.	
„ 19.	Railway Tank, Sealdah.		Do.	Almost colorless, slight smell, small quantity suspended matter, no visible animal life.	0·80	452·60	Do.	
„ 20.	128-J, Bow Bazar Street.	K	Do.	Almost colorless, no smell, very small quantity suspended matter, no visible animal life.	0·60	450·85	Do.	
„ 22.	20, Bamutollah Street.	B	Do.	Yellow color, unpleasant smell, much suspended matter, animal life.	48·00	816·50	Do.	
„ 25.	34, Serang's Lane.	N	Do.	Almost colorless, slight smell, small quantity suspended matter, no visible animal life.	0·94	603·50	Do.	
„ 28.	1-D, Nemoo Gawsat's Lane.	B	Do.	Yellow color, unpleasant smell, much suspended matter, no visible animal life.	17·52	514·75	Do.	Filled up.

Well Waters, 1878—*Continued.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the well.
Feb. 28.	13-J, Patwai Bagan.	I	Cholera death in neighbourhood.	Yellowish color, slight smell, small quantity of suspended matter, no visible animal life.	0·94	603·50	Condemned.	
„	21, Nathu Bagan.	B	Do.	Brownish color, unpleasant smell, slightly opalescent, small quantity suspended matter.	41·06	532·50	Do.	
„	1, Nemoo Gosain's Lane.	B	Do.	Brownish color, stinks, suspended matter, and much animal life.	6·96	390·50	Do.	
Mar. 4.	71, Dhurumtollah Street.	B	Do.	Yellow color, slight smell, small quantity suspended matter, no animal life.	3·36	319·50	Do.	
„	9, Boloram Mozoomdar's Street.	B	Do.	Black color, horrible stench of sulphuretted hydrogen, very opalescent, much suspended matter.	11·17	492·00	Do.	
„ 7.	168, Cotton Street.	E	Do.	Slight yellowish tinge, slight smell, little suspended matter.	0·20	195·25		
„	113, Dhurumtollah Street.	E	Do.	No smell, small quantity suspended matter, no visible animal life.	2·50	53·25	Do.	
„	82-5, Burtollah Street.	E	Do.	Full yellow color, slight smell, much suspended matter, distinct animal life visible under microscope.	222·00	781·00	Do.	
„ 8.	27, Bonomally Sircar's Street.	B	Do.	Almost colorless, very slight smell, little suspended matter, distinct animal life under microscope.	18·60	319·50	Do.	
„ 5.	23-9, Durponaryan's Lane.	E	Do.	Almost colorless, very slight smell, much suspended matter, no visible animal life.	14·80	514·75	Do.	
„	17-22, Durponaryan's Tagor's Street.	E	Do.	Slight yellowish color, very slight smell, little suspended matter, no animal life.	2·00	284·00	Do.	
„ 5.	3, Antony Bagan Lane.	I	Do.	Yellowish color, no smell, little suspended matter.	9·48	230·75	Do.	

Mar. 5,	25, Baranosee Ghose's Street.	F	Cholera death in neighbourhood.	Greyish white color, stinks badly, very opalescent, much suspended matter.	1·92	71·00	Condemned.
,, 6.	7-a, Bysack's Lane.	E	Do.	Deep brown color, unpleasant smell, opalescent.	219·00	1384·5	Do.
,,	124, Manicktollah Street.	D	Do.	Yellow color, stinks badly, little suspended matter, no animal life.	35·74	727·75	Do.
,, 8.	21, Machoo Pal's Street.	B	Do.	Almost clear, transparent and colorless, no smell, no visible animal life.	5·24	213·00	Do.
,, 11.	6, Ashutosh Dey's Lane.	F	Do.	Colorless, slight smell, little suspended matter, no visible animal life.	9·96	319·50	Do.
,,	5, Suri's Lane.	K	Do.	Blackish color, stinks badly, very opalescent, full of suspended matter, animal life.	68·00	550·25	Do.
,,	12, Nilmony Mitter's Lane.	C	Do.	Almost colorless, very slight smell, little suspended matter, no animal life.	8·52	426·00	Do.
,, 12.	82-17, Burtollah Street.	E	Do	Almost colorless, slight smell, small quantity suspended matter.	0·46	126025	Do.
,,	14-C, Goomgur Lane.	G	Do.	Yellowish color, nasty smell, little suspended matter.	3 31	727·75	Do.
,,	222, Cornwallis Street.	F	Do.	Yellowish color, very unpleasant smell, little suspended matter, animal life.	5·68	177·50	Do.
,,	1, Ram Chunder Banerjee's Lane.	I	Do.	Almost colorless and transparent, very little suspended matter.	0·60	35·50	
,, 13.	22, Free School Street.	M	Do.	Greenish yellow color, unpleasant smell, much suspended matter.	5·04	337·25	Do.
,,	15, Nilmony Mitter's Lane.	C	Do.	White color, slightly opalescent, little suspended matter, animal life.	5·04	319·50	Do.
,,	135, Machooa Bazar Street.	F	Do.	Yellowish green color, slight smell, much suspended matter, animal life.	22·40	1029·5	Do.
,,	54, Old Boytuckhana Bazar Street.	I	Do.	Almost colorless, no smell, little suspended matter, no visible animal life.	3·62	532·50	Do.

Well Waters, 1878—*Concluded.*

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Chlorine parts per million.	Whether condemned for domestic purposes or not.	What was done to the well.
July 12.	27, Zig Zag Lane.	J	Complaint.	Brownish color, faint smell, much suspended matter, animal life.	0·10	85 20	Condemned.	
„ 15.	48-2-2, Bulloram Dey's St.	F	Complaint.	Deep yellow brown color, unpleasant smell, large quantity of suspended matter, animal life.	7·20	426·00	Do.	
Sep. 23.	Gangaram Barick's Well, 4, Bysack Bagan Lane.	F	For improving Gowala Bustee.	Deep yellow brown color, slight smell, small quantity of suspended matter, no visible animal life.	45·12	869·75	Do.	
„ 24.	Jogendra Nath Matee, 4, Bysack Bagan Lane.	F	For improving Gowala Bustee.	Yellow brown color, unpleasant smell, small quantity of suspended matter, visible animal life.	46·80	852·00	Do.	
Dec. 16.	19, Durjeepara Street.	C	Cholera in neighbourhood.	Almost colorless, no smell, small quantity of suspended matter, no visible animal life.	3·07	213·00	Do.	
„ 17.	1, Outram Street.	O	Complaint.	Slight color, stinks on keeping, considerable quantity of suspended matter.	4·52	17·75	Do.	
„ 18.	4, Nursing's Lane.	I	Cholera in neighbourhood.	Yellow color, faint unpleasant smell, no suspended matter.	7·28	301·75	Do.	
„ 19.	340, Upper Chitpore Road.	B	Do.	Yellow color, slight unpleasant smell on keeping, small quantity of suspended matter.	1·17	213·00	Do.	

Well Waters, 1879.

Date.	Locality.	Section.	Reason why water was submitted to analysis.	Description.	Total Ammonia parts per million.	Chlorine parts per million of water.	Whether condemned for domestic purposes or not.	What was done to the well.
Jan. 10.	14-2-89, Machooa Bazar Street.	H	On the receipt of objection from the owner to dewater.	Almost colorless, no smell, small quantity suspended matter, animal life.	0·33	639·00	Condemned.	
,, 15.	69, Sitanarain Ghosh's Street.	I	Do.	Yellow color, no smell, opalescent, contains suspended matter.	12·60	372·75	Do.	
June 17.	29, E. Gopee Kristo Paul's Lane.	B	Do.	Bright yellow color, unpleasant smell, small quantity suspended matter, no animal life.	7·92	301·75	Do.	
				1880.				
Jan. 23.	6, Brindabun Mullik's Lane.	D	Complaint.	Black color, stinks abominably, large quantity of suspended matter, animal life.	64·00	514·75	Do.	

Taking the results obtained by the Total Ammonia Test, and judged by the standards which have been put forward by Prof. Wanklyn, and the additional somewhat rough ones suggested by myself, it will be seen, as might be expected, that no single tank or well water was of extraordinary organic purity, and that there were only seven tank waters included under the head of "safe" waters, five of which were from tanks on the maidan. Of dirty waters there were 26 out of the 200 or 13 per cent.; of waters considerably contaminated with sewage matter 64 were found, or 32 per cent.; of dilute sewages there were 32, or 16 per cent.; and of real genuine sewages 71 were found or 35½ per cent., that is rather more than one third of the whole number.

In the following table these results are separated into the two classes of tank and well waters, and it will be seen that the impurity of both descriptions of waters is nearly equal when judged by this test.

	Sewages more than 10 parts of total ammonia.	Dilute Sewages from 10 to 5 parts of total ammonia.	Waters contaminated with considerable quantities of sewage, from 5-1 parts of total ammonia.	Dirty waters from 1 to 0·1 parts of total ammonia.	Safe waters from 0·1 to 0·05 parts of total ammonia.	Very pure waters less than 0·05 parts of total ammonia.	Total.
Tank waters, ...	52	19	36	10	7	0	124
Percentage, ...	42	15	30	7	6	0	100
Well waters, ...	19	13	28	16	0	0	76
Percentage, ...	25	17	37	21	0	0	100
Percentage of both well and tank water, ...	35½	16	32	13	3½	0	100

In considering the quantities of chlorine present, notice must be taken of the fact that in a well water the amount of chlorine will be relatively greater than that of the total ammonia derived from the organic matter, because in the filtration of the water through the soil to reach the well, all the insoluble portions of the organic matter present in the sewage, etc., will be stopped, whilst the chlorides will readily pass through in solution. Again in the filtration of contaminated water through layers of earth or soil, a certain proportion of the organic matter will be oxidized and converted into inorganic compounds such as nitrates, which will not yield any ammonia on distillation with alkaline potassium permanganate. Thus we may expect, that a larger proportion of the well waters will be condemned by the chlorine process than would be condemned by the total ammonia test.

The following table will show the classification of the tank and well waters according to the amounts of chlorine.

	Sewages containing more than 250 parts of chlorine per million.	Dilute sewages containing from 250 to 150 parts of chlorine per million.	Waters contaminated with considerable quantities of sewage containing from 150 to 100 parts of chlorine per million.	Dirty waters containing from 100 to 50 parts of chlorine per million.	Moderately safe waters containing from 50 to 20 parts of chlo. per million.	Good waters less than 20 parts of chlorine per million.	Total.
Tank waters,...	56	38	14	6	7	3	124
Percentage, ...	45	30	11	5	6	3	100
Well waters,...	49	18	1	5	2	1	76
Percentage, ...	64	24	1	7	3	1	100
Percentage of well and tank waters, ...	$52\frac{1}{2}$	28	$7\frac{1}{2}$	$5\frac{1}{2}$	$4\frac{1}{2}$	2	100

It would of course be quite permissible to consider waters which have been condemned by *either* of these two methods to be sewages, dilute sewages or unfit for domestic use, etc., but on inspection of the tables it will be seen, that as a general rule a water which is condemned by the total ammonia test is also condemned by the amount of chlorine present.

The results, however, are sufficiently startling, if we only take the mean of the results of the two determinations; and at the very lowest estimate it must be said, that of the 200 samples of Calcutta tank and well waters examined by me, forty-four per cent. were true sewages, twenty-two per cent. were dilute sewages, twenty per cent. of the waters were contaminated with considerable quantities of sewage, nine per cent. were "dirty waters," and about four or five per cent. only were moderately safe waters. These last consisted principally of the well kept tanks on the maidan, and two or three others in the southern part of the town.

In the next table I have grouped the well and tank waters according to the sections of the town to which they belong; in this table I have given, first the name of each section and its population per acre according to the census of 1876, then the total number of waters analysed from each section, with their classification according to the plan before adopted. There is also given the average composition of all the waters analysed in each section. It will be strikingly seen from this table, how much more impure the tanks and wells of the northern divisions are, than those of the southern sections of the town.

Name of Section.	Sectional letter.	Population per acre by Census of 1876.	No. of waters analysed.	No. classed as Sewages.	No. classed as Dilute Sewages.	No. classed as waters containing considerable quantities of sewage.	No. classed as Dirty waters.	No. classed as Moderately Safe waters.	No. classed as Good waters.	Average composition of all waters. Total ammonia parts per million.	Chlorine parts per million.
A. *Tank Waters.*											
Shampooker, ...	A	75	10	4	1	5	0	0	0	8·86	339·0
Koomartooly, ...	B	163	4	3	1	0	0	0	0	12·60	377·2
Burtolla, ...	C	84	21	15	2	4	0	0	0	14·62	367·7
Sookea's Street, ...	D	87	14	5	2	6	1	0	0	6·48	215·3
Jorabagan, ...	E	152	1	1	0	0	0	0	0	17·00	319·5
Jorasanko, ...	F	137	6	4	1	1	0	0	0	26·21	295·8
Burra Bazar, ...	G	108	2	1	0	0	1	0	0	4·24	191·6
Colootollah, ...	H	214	1	1	0	0	0	0	0	92·40	177·5
Moocheeparra, ...	I	141	2	1	1	0	0	0	0	8·20	199·1
Bow Bazar, ...	J	156	4	2	0	2	0	0	0	21·93	209·5
Puddopooker, ...	K	119	13	11	2	0	0	0	0	51·77	307·2
Waterloo Street,... ...	L	27	0	0	0	0	0	0	0		
Fenwick Bazar, ...	M	135	3	1	0	0	2	0	0	4·96	164·0
Taltollah, ...	N	124	14	7	3	4	0	0	0	23·70	241·9
Colinga, ...	O	72	10	1	2	6	1	0	0	5·13	164·0
Park Street, ...	P	23	0	0	0	0	0	0	0		
Bamun Bustee, ...	Q	30	3	1	1	0	1	0	0	7·17	162·1
Hastings, ...	R	86	3	0	0	0	0	2	1	0·09	53·0
Maidan, ...	...	...	5	0	0	0	0	2	3	0·09	19·1
B. *Well Waters.*											
Shampooker, ...	A	75	1	1	0	0	0	0	0	12·80	582·2
Koomartooly, ...	B	163	12	8	3	1	0	0	0	17·90	466·1
Burtolla, ...	C	84	5	1	1	3	0	0	0	3·99	240·0
Sookea's Street, ...	D	87	2	2	0	0	0	0	0	49·87	621·2
Jorabagan, ...	E	152	25	5	2	16	2	0	0	21·17	371·7
Jorasanko, ...	F	137	7	5	1	1	0	0	0	19.87	535·0
Burra Bazar, ...	G	108	6	0	1	3	2	0	0	1·82	410·8
Colootollah, ...	H	214	1	0	0	1	0	0	0	0·33	639·0
Moocheeparra, ...	I	141	7	2	2	2	0	1	0	5·58	299·4
Bow Bazar, ...	J	156	2	0	1	0	1	0	0	1·71	406·5
Puddapooker, ...	K	119	4	2	0	2	0	0	0	18·95	518·7
Fenwick Bazar, ...	M	135	2	1	1	0	0	0	0	6·62	426·0
Taltollah, ...	N	124	2	0	1	1	0	0	0	2·12	541·4

In classifying these waters I have not separately considered the two numbers I obtained by analysis for the total ammonia and chlorine, but have decided on the character of each water from the amounts of both these substances, and this table would therefore show the exact character which I have attached to the waters which I have analysed.

I scarcely think that it is necessary to criticise in detail the numbers which I have obtained in these analyses. In some instances the results of analyses showed that the tank and well waters are considerably more impure than the very concentrated Calcutta sewage, which was collected at the Pumping Station on December 18th, 1876. I have indeed never read in any work or research of such horribly filthy waters as these are, and they are waters which are now, or have been formerly used for domestic purposes by many of the poorer inhabitants of Calcutta.

Taking the numbers given in the foregoing tables, it may be said as a general result of the whole of these analyses, that an average Calcutta tank or well water contains 16·2 parts of total ammonia and 320·6 parts of chlorine per million of water. This it will be remembered from one of the previous tables, is if anything rather more impure than ordinary English sewage as obtained and analysed by Prof. Wanklyn. In the table referred to Prof. Wanklyn found in a sample of sewage 17·10 parts of Total Ammonia and 141·4 parts of Chlorine. We may also say that the average Calcutta tank or well water contains more than 400 times as much organic nitrogenous matter as is usually present in the hydrant water.

I have, however, no wish to enlarge to any extent on this decidedly nauseous topic, but perhaps the most striking condemnation of the well and tank waters of Calcutta, and which will appeal to every inhabitant, whether scientific or otherwise, is to say, that a good average quality of Calcutta tank or shallow well water may be made, by mixing six parts of our present hydrant water with from one to two parts of the most concentrated Calcutta sewage. This artificial tank or well water will be of about the average composition; it will also be so far as can be judged, equally healthy for potable and domestic purposes, and as for its taste, odour, etc., it will probably be rather superior to the general run of Calcutta tank and well waters.

So far as I can ascertain this was the kind of water which was commonly used for drinking and domestic purposes in Calcutta in former days, and which may to a certain extent be still used by the poorer inhabitants of the northern quarter of the town.

The present water supply, i. e., the Hydrant water.

I need scarcely mention that our present hydrant water consists of the Hooghly water pumped from the river at Pultah; it is there collected in settling tanks, and after subsidence it is filtered through sand and then supplied to Calcutta. As I have made some remarks as to the quantity of the former water supply of Calcutta, this paper would not be complete if I did not refer to the quantity of our present supply. From the Report of the Municipality for the year 1879, I find that as the average for the whole year, 7,461,159 gallons of filtered water were daily supplied to the town. According to Mr. Beverley's Census of 1876, the number of inhabitants was 429,535, and each inhabitant would therefore receive 17·4 gallons of filtered water daily. But in addition to the filtered water, there is an unfiltered supply pumped up at Chandpal Ghat which is widely distributed through the town, where it is I believe used for such purposes as watering the roads and streets, flushing latrines and sewers, filling reserved tanks, etc. The daily unfiltered supply was on the average of the whole year, 1,091,866 gallons, and therefore the total daily supply in Calcutta for the past year was 8,556,025 gallons, equivalent to 19·92 gallons per head, or practically there were 20 gallons of water available for domestic and sanitary purposes for each inhabitant. This though perhaps not an abundant supply is a fairly liberal one, and is very much larger than the quantity of the old supply from tanks and wells. It is, however, not equal to the quantity allowed in most European towns, for as pointed out in a former part of this paper the average daily water supply of English towns is at least 25 gallons per head of population. In this country, however, it would appear that a more liberal supply would be required than in a European climate, and it has therefore been proposed to double the present amount of filtered water, in which case Calcutta would receive a daily supply of 16,000,000 gallons equivalent to 37·2 gallons per head. If this proposal is carried out, the supply of filtered water will be most abundant, and it will be amply sufficient for every possible want of the town so long as it keeps to its present dimensions.

The quality of the hydrant water as I mentioned before has been determined for four years, month by month, by Dr. Frankland's process of analysis. This is certainly the most elaborate and complete method discovered, and it is believed to show the quality of a water, not only as regards its present actual constituents, but also to indicate to a certain extent, what its previous history has been. In this process it may be stated the following operations are performed: first the amount of total solids dissolved in the water is estimated, then the amounts of carbon and nitrogen present in the organic matter are determined (these are called organic carbon and organic nitrogen in the following tables); next the amount of free ammonia present (if any) is determined, and the amount of nitrogen contained in the form of nitrates or nitrites is estimated; the amount of chlorine present as chlorides is also determined, and finally the hardness of the water, temporary, permanent and total is estimated. Of these determinations the second, third, fourth and fifth are the most important from a hygienic point of view. Thus the amounts of organic carbon and nitrogen represent the organic matter existing as such in the water, at the time of analysis. The ammonia may to a certain extent be due to the original ammonia we find in rain water, but more generally it may have been produced by the introduction of sewage matter into the water. The nitrates and nitrites present in water are derived from the oxidation of nitrogenous organic matter; this oxidation may have taken place either in the water itself, or in the soil on which the rain water fell. These last constituents are to be looked on with suspicion unless the water is derived from a deep well, when it may contain considerable quantities of these substances without giving rise to any alarm. It is not that nitrates in themselves are injurious in any way, but their occurrence in any quantity in river or shallow well waters shows, that the water must have been either contaminated with some nitrogenous organic matter in a state of decomposition, or in some circumstances where decomposing nitrogenous organic matter had been previously present. It is pointed out that it must be more or less dangerous to drink water that has thus been contaminated with organic matter or with nitrates derived from organic matter, for it is possible if not probable that in such a water the most noxious of all its constituents would entirely escape oxidation or any kind of change. The reason for this opinion is very clearly expressed in one of Dr. Frankland's papers on potable water. In the Journal of the Chemical Society, March 1868, at page 31 of his Memoir, he says—"There is also another aspect in which the previous sewage contamination of a water (*i. e.*, the presence of large quantities of nitrates etc.) assumes a high degree of importance; if the shell of an egg were broken, and its contents beaten up with water, and thrown into the Thames at Oxford, the albumen would probably be entirely converted into mineral compounds before it reached Teddington, but no such destruction of the nitrogenous organic matter would ensue, if the egg were carried down the stream unbroken for the same distance; the egg would even retain its vitality under circumstances which would break up and destroy dead or unorganised organic matter. Now excrementitious matters certainly, sometimes, if not always, contain the germs or ova of organized beings, and as many of these can doubtless retain their vitality for a long time in water, it follows that they can resist the oxidizing influences which destroy the excrementitious matters associated with them. Hence great previous sewage contamination in a water means great risk of the presence of these germs, which, on account of their sparseness and minute size, utterly elude the most delicate determinations of chemical analysis." A considerable number of chemists have put forward the statement, that a river water which has been contaminated with sewage matters will entirely purify itself in a flow of a few miles, and will thus again become fit for potable and domestic purposes. The weight of the evidence appears however to disprove this statement, and further experiments made by Dr. Frankland have shown that this oxidation of sewage matter when present in running water is a process of extreme slowness. Thus in the report of the Rivers Pollution Commissioners, he writes:

"Assuming, however, that if the polluted water had been constantly exposed to the air, a portion at least of the oxygen used would have been replaced, and assuming further that the oxidation proceeded during 168 hours at the maximum rate observed, then at the end of that time, only 62·3 per cent. of the sewage would be oxidized.

"It is thus evident that so far from sewage mixed with 20 times its volume of water being oxidized during a flow of 10 or 12 miles, scarcely two-thirds of it would be so destroyed in a flow of 168 miles, at the rate of one mile per hour, or after the lapse of a week. But even this result is arrived at by a series of assumptions which are all greatly in favour of the efficiency of the oxidizing process. Thus, for instance, it is assumed that 62·3 per cent. of sewage is thoroughly oxidized, and converted into inoffensive inorganic matter, but the experiments showed that, in fact, no sewage matter whatever was converted or destroyed even after the lapse of a week, since the amount of carbonic acid dissolved in the water remained constant during the whole period of the experiment, whilst, if the sewage had been converted into inorganic compounds, the carbonic acid, as one of these compounds, must have increased in quantity.

"Thus, whether we examine the organic pollution of a river at different points of its flow, or the rate of disappearance of the organic matter of sewage when the latter is mixed with fresh water, and violently agitated in contact with air, or finally, the rate at which dissolved oxygen disappears in water polluted with 5 per cent. of sewage, we are led in each case to the inevitable conclusion, that the oxidation of the organic matter in sewage proceeds with extreme slowness, even when the sewage is mixed with a large volume of unpolluted water, and that it is impossible to say how far such water must flow before the sewage matter becomes thoroughly oxidized. It will be safe to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

Thus Dr. Frankland is of opinion that a river water once largely contaminated with sewage or organic matter can never of itself become sufficiently pure again to be a safe water supply. To this point I shall again have occasion to refer, when speaking of the proposed sources of the new supply.

From these remarks it will be seen that in judging of the quality of a potable water by Frankland's process of analysis, we pay the greatest amount of attention to the amounts of ammonia and of organic carbon and nitrogen, as representing organic matter actually present, whilst we depend upon the amount of nitrates (and to a considerable extent also on the amount of chlorides as explained in the previous part of this paper) to indicate organic contamination which has become oxidized. The amounts of total solids and of Hardness although important from a manufacturer's point of view, do not seem to have any marked action on the health of persons drinking such water, except when such constituents are present in very large quantities.

Dr. Frankland has unfortunately not fixed upon any very definite standard as to the amounts of the above substances which may be present in water and yet not render it dangerous, and in fact it is almost impossible to draw any hard and fast rule; but so far as can be ascertained from his writings, Dr. Frankland appears to think that a supply which contains 0·10 parts of organic carbon and nitrogen in every hundred thousand parts of water is of "great organic purity," whilst one containing 0·30 parts of the same substances in the same volume should be considered a water of "fair organic purity." If the quantity is above this a water would be of doubtful purity, and if in still larger quantities the water would be recognized as impure.

In order to give an idea of the quantities of these various substances present in the water supplies of many of the large towns in England, and to show the average composition of different samples of water from various sources, I append a table giving the results by this method of analysis of the London water supply from the rivers Thames and Lea, and from the deep wells in the chalk, also the results of the Edinburgh, Glasgow, Liverpool, Manchester and Dublin water supplies, and the average composition derived from the analysis of a large number of samples of rain water, upland surface water, spring water, and sea water. Most of these numbers are taken from the various reports of the Royal Commissioners who were appointed to investigate the Pollution of Rivers in England, but some of the numbers come from the article on Water Analysis given in "Sutton's Volumetric Analysis."

See Table, page 120.

Having thus settled our standards for comparison, we can now discuss the present water supply of Calcutta. The results obtained by the analysis of the Hydrant water are given in the following table; the numbers shown for each month are the averages for the past four years, and at the foot of the table, the general average for the whole of the four years is appended.

See Table, page 121.

Results of Analysis expressed in parts per 100,000.

	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
London Water supply, average for 7 years.											
From the Thames, ...	27·26	·201	·033	·001	·204	·238	1·77	...	...	21·20	
From the Lea, ...	27·79	·135	·024	·000	·199	·223	1·79	...	...	21·30	
From the Deep-wells in the Chalk, ...	40·26	·047	·012	·000	·421	·433	2·43	...	...	28·70	
Edinburgh water supply, ...	14·10	·203	·042	·000	None.	·042	0·89	4·40	4·80	9·20	
Glasgow water supply from Loch Katrine, ...	2·40	·185	·022	·001	Do.	·023	0·85	0·00	0·90	0·90	
Liverpool water supply, ...	9·66	·210	·029	·002	Do.	·031	1·53	0·30	3·70	4·00	
Manchester do., ...	7·00	·132	·031	·002	Do.	·033	0·90	0·00	2·70	2·70	
Dublin do., ...	6·34	·238	·024	·001	Do.	·025	1·24	0·00	2·97	2·97	
Switzerland the Rhine above Schaffhausen,	15·80	·108	·012	·003	Do.	·015	0·20	3·99	6·77	10·76	
London Sewage, ...	64·50	4·386	2·484	5·557	Do.	7·060	10·37	...	...	...	
Average composition of UNPOLLUTED WATER.											
Rain water 39 samples, ...	2·95	·070	·015	·024	·003	·042	0·22	...	...	·30	
Upland surface water 195 „	9·67	·322	·032	·002	·009	·043	1·13	1·50	4·30	5·80	
Deep well water 157 „	43·78	·061	·018	·010	·495	·523	5·11	15·80	9·20	25·00	
Spring water 198 „	28·20	·056	·013	·001	·383	·397	2·49	11·00	7·50	18·50	
Sea water 23 „	3898·7	·278	·165	·005	·033	·203	1975·6	48·90	748·00	796·90	

CALCUTTA HYDRANT WATER.

Average results from the Analysis of four years.

Results of Analysis expressed in parts per 100,000.

	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness. Temporary.	Hardness. Permanent.	Hardness. Total.	Remarks.
Average for 1st of January, ...	21·57	·131	·037	None.	·016	·053	0·87	3·72	2·97	6·69	
Do. February	21·79	·179	·058	Do.	·035	·093	1·00	3·56	2·92	6·48	
Do. March, ...	22·37	·114	·063	Do.	·048	·111	1·20	3·64	2·97	6·61	
Do. April,...	21·68	·124	.046	Do.	·034	·080	1·32	3·07	2·72	5·79	
Do. May, ...	21·23	·120	·045	Do.	·030	·075	1·37	3·08	3·16	6·24	
Do. June,...	19·43	·155	·037	Do.	·017	·054	1·37	2·44	3·79	6·23	
Do. July, ...	13·04	·093	·044	Do.	·049	·093	0·85	1·65	2·83	4·48	
Do. August, ...	12·07	·081	·047	Do.	·055	·102	0·67	0·93	2·64	3·57	
Do. September, ...	11·36	·104	·049	Do.	·046	·095	0·58	1·34	3·00	4·34	
Do. October, ...	11·30	·099	·050	Do.	·027	·077	0·61	1·39	3·32	4·71	
Do. November, ...	12·27	·118	·054	Do.	·021	·075	0·73	2·15	2·92	5·07	
Do. December, ...	19·44	·090	·042	Do.	·025	·067	0·88	2·55	2·93	5·48	
Sums, ...	207·55	1·408	·572	Do.	·403	·975	11·45	29.52	36·17	65·69	
Average for year	17·30	·117	·047	Do.	·034	·081	0·95	2·46	3·02	5·48	

Taking the numbers representing the general average for the year and comparing them with the standards which I have suggested from Dr. Frankland's works, we find that the Calcutta water falls just outside the class of waters of "great organic purity," but that it is well within the class of waters of "fair organic purity."

Comparing again the numbers with those given in the previous table we find that the Calcutta Hydrant water though not so pure as the London waters derived from the deep wells in the Chalk, is certainly purer than the waters derived from the Thames, and perhaps also from the Lea. It is also decidedly more free from impurity than the water supplies of Edinburgh, Liverpool and Dublin, but taking all the constituents into consideration, it is not so pure as the Glasgow or Manchester supplies, or as the Rhine water above Schaffhausen. Comparing the Hydrant water with the average composition of *unpolluted* upland surface water as given by Dr. Frankland, we find that it is scarcely so pure as unpolluted water should be, and we are therefore compelled to admit that the Hooghly water has been slightly contaminated before it reaches Pultah. The amount of contamination is, however, not very great and as pointed out before, the Calcutta water falls well within the class of waters of medium purity. That the Calcutta water must be contaminated to a certain extent will be I think obvious to any one who is acquainted with the customs of the inhabitants of India, and more particularly of the inhabitants of villages and towns on the banks of the rivers. This contamination is a drawback to the complete safety of our water supply, for as pointed out previously, Dr. Frankland is of opinion, that a water once contaminated is always dangerous, and that the self-purification of a river which is so strongly insisted upon by certain persons is exceedingly slight. It does not however at present appear to be possible to cut off these sources of contamination, and the Hydrant water though good is not a perfect supply. Every effort however should be made to keep this previous contamination down to the lowest possible point, and it is to be hoped when systems of drainage are being introduced into the up-country towns, that the sewage from them will not be allowed to find its way into our river. Speaking generally the sewage from any one town should not be allowed to find its way into a river which is used as a source of water supply for other towns lower down.

It is not my intention to criticise these average numbers in detail, but it will suffice to say that from the absence of ammonia and from the smallness of the amounts of organic carbon and nitrogen, and of nitrates and nitrites, and also of chlorine, it is clearly evident that the contamination of the Calcutta water is really much smaller than might have been expected under the circumstances, and we may rest assured that our water supply is of fairly good quality, better in fact than that received by the majority of large towns in Europe.

In considering the results of the analysis of the Calcutta water month by month, we find that its composition varies considerably at different parts of the year. A close inspection of the table will show that apparently there are two distinct causes at work in modifying the composition of the water. The first prominent cause, and the one which has by far the greater influence, is to be found in the commencement, and during the continuance of the rainy season ; the second and smaller cause appears to be the melting of the Himalayan snows by the burning sun of March, April, May and June. These changes are most clearly noticed in the column of Total Solid Impurity, and here we read that starting in January the amounts of total solids gradually increase up to March, when 22·37 parts are present in every hundred thousand parts of water ; in April and May the quantities steadily and gradually diminish, the numbers being 21·68 and 21·23 respectively ; this decrease continues until June 1st when there are only 19·43 parts of solid impurity present. These numbers of course correspond with the gradual and increasing diluting effect due to the admixture of pure snow water with the ordinary river water. In the middle of June, however, the rainy season usually commences, and there is a sudden decrease in the solids owing to the diluting action of the enormous volumes of rain water, and we find only 13·04 parts on July 1st ; from this time there is a slight but steady decrease until October, when the water contains the smallest amount of solids present at any time of the year ; the average for October 1st showing 11·30 parts. After the complete cessation of the rains (after November 1st) there is again a sudden rise in the total solids, and on December 1st, 19·44 parts are present. Some of the other columns of figures show a somewhat similar change, but in the case of the organic matter the change is not very marked. In the amount of nitrates present in the water, there appear to be two distinct maximum quantities during the year, one in March at the time of greatest concentration of the water as before mentioned, and the second at the commencement of the rains. This second maximum is readily accounted for when we consider, that the first effect of the rains will be to dissolve out the nitrates which have been accumulating in the soil of the drier parts of the country during the hot season ; the amount of nitrates, however, it will be seen, steadily decreases towards the end of the rains, and this to a certain extent confirms the explanation.

Indeed during the first weeks or even days of the rainy season, the composition of our water supply is undergoing very rapid change, owing to the diluting action of the rain, and to the fact that the first showers of rain will wash out considerable quantities of soluble organic matter, nitrates etc., from the soil ; afterwards, however, the rain water will run off comparatively pure. We shall therefore expect that the first action of the rain will be to decrease the total solids, and to increase the amounts of organic impurity and of nitrates, and that afterwards all the constituents will decrease in quantity.

That such is the case may be seen by the following analyses made on June 1st, 23rd and 26th and July 1st of last year. Each of the analyses shows the gradual dilution of the water by the heavy falls of rain in the districts from which our supply is collected, and the increase of organic matter and of nitrates due to the washing out of the substances from the soil by the first showers of rain.

HOOGHLY WATER.

Results of Analysis expressed in parts per 100,000.

Number of Sample.	Date of collection of Sample.	Total solid Impurity.	Organic Carbon.	Organic Nitrogen.	Ammonia.	Nitrogen as Nitrates and Nitrites.	Total Combined Nitrogen.	Chlorine.	Hardness.		
									Temporary.	Permanent.	Total.
1	June 1st, 1879,	19·56	0·130	0·052	·000	Traces only.	0·052	1·32	4·24	2·45	6·79
2	June 23rd, "	17·08	0·148	0·099	·001	·023	0·123	0·923	3·46	3·25	6·71
3	June 26th, "	16·68	0·138	0·075	·002	·053	0·130	0·852	3·33	3·38	6·71
4	July 1st, "	12·48	0·113	0·093	·000	·039	0·132	0·89	0·72	4·57	5·29

Extension of the Present Water Supply.

As pointed out previously it is now proposed to double the supply of filtered water for Calcutta, and recently a proposal has been urged on the Corporation to collect the new supply of water at Cossipore or Dukhinsahar instead of as at present at Pultah. As I was consulted on this subject and gave a strong recommendation that the water should not be taken from any place near to Calcutta, but that the present source at Pultah should still be used, I may perhaps be allowed to give the substance of my arguments against the two proposed sources of supply at Cossipore and at Dukhinsahar.

My opinions on this point are to a great extent founded on some previous analyses of the river water taken at various points near to Calcutta, which were made by Dr. Macnamara and Mr. Waldie, when the Calcutta supply was first being introduced, but in addition I have myself made a few analyses which have confirmed me in my conclusions.

The usual time for pumping up the water from the river into the settling tanks is at five hours' ebb ; this is of course done so as to avoid the possibility of taking in any tidal water and as far as possible to secure only the true river water. The proposals for taking the water for these two places appeared then to resolve themselves into two questions.

(*a*) Whether at five hours of ebb the water off Cossipore, *at all seasons of the year* can be relied on as a safe source of water-supply.

(*b*) Whether at five hours of ebb, the water at a distance of two or three miles above Cossipore, *at all seasons of the year*, can be relied on as a safe source of water-supply. For I think it will be generally admitted, if at either place, at any one season of the year, the quality of the water cannot be relied on, this would be equivalent to a condemnation of the proposed place of supply.

Before proceeding to deal with the actual results of the analyses which have been previously made by the two gentlemen abovementioned, it will be well to take a general review of the conditions of our river from which the water-supply is to be derived. The river, as is well known, is a tidal one to a considerable distance above its mouth, and it appears certain that the tidal water does not at any season of the year, or under any ordinary circumstances, reach higher than Chinsurah. I have already shown in a previous part of this paper that the true river water, as it has been delivered of late years in Calcutta, is a tolerably pure and reliable supply, and that there has never been the slightest suspicion of any appreciable admixture of tidal water with the natural river water, in the hydrant water now supplied from Pultah. This of course, is because the water is collected at a considerable distance up the river, and that it is taken at five hours' ebb.

The tidal water however, in flowing up past Calcutta undoubtedly, must become contaminated with a variety of impurities. It may be true that a large proportion, or perhaps nearly the whole of the sewage, as collected in the drains of this town, is now carried to the Salt Water Lakes, but no one, knowing the habits of the lower orders of the natives of this country, will believe, that this represents the sum total of the sewage. In all probability, there is a large amount of filth of various kinds, which finds its way direct into the river. Again, on the banks of the river numerous factories have now sprung up, and it will be quite unlike the usual experience in England if these factories, unrestrained by Acts of Parliament, do not also send a large amount of filth, refuse, &c , into the running stream beside them. I am not aware what sanitary arrangements are made on the Howrah side of the river, but it has always appeared to me, that a large amount of drainage reaches the river from that source.

Also it must be remembered that Calcutta is a large shipping port; thus on the average I believe there are about 2,000 vessels annually arriving and departing from the port, aggregating nearly two and a half millions of tons; to these must be added the very large numbers of country boats, dinghis, &c., which line the shores and which help to carry on the great and increasing trade of Calcutta. Omitting the actual business operations carried on, it must be admitted, that the crews of these vessels will add a not inconsiderable amount of sewage contamination to the river water. The tidal water, in flowing past Calcutta, must of necessity then carry with it all such contamination, and will in that state be probably, if not certainly, unfit for drinking, or even for domestic purposes.

I think it cannot be disputed that, in selecting a site from which to collect water for *drinking and domestic* purposes, it will be essential, that at all seasons of the year, at the ordinary time of collection, (five hours' ebb) there shall be practically no admixture of tidal water with river water proper; for it is evident, that the tidal water will always be contaminated with various kinds of organic matter.

The two questions which I suggested previously, thus become limited to the consideration of whether at Cossipore, or at two or three miles above it, the water at five hours' ebb is free from contamination with tidal water at *all* seasons of the year. It would be bad enough to supply brackish tidal water for drinking purposes, but far worse to supply tidal water, which had collected all sorts of filth and abomination on its way up.

Having suggested what it appears necessary to prove, we can now pass on to the consideration of the analyses which have been made on this point. Most of these analyses were made from 12 to 18 years since, when comparatively little attention had been given to the subject of water analysis, and an important part of the method of analysis then employed has been since shown to be eminently untrustworthy and unreliable. The suitability of a water for domestic purposes is (as pointed out previously) believed to depend principally on its freedom from organic contamination, I am sorry to say that the methods for the determination of organic matter in water, used in the old analyses under notice, have been since shown to give at the best but very rough indications, which do not at all represent the absolute amounts of organic matter present. Though these methods of analysis failed to give thoroughly reliable information, yet I do not think it too much to assume that, to a certain extent, they gave information as to comparative purity of samples of the same variety of water, and valuable information may thus be extracted from them. By this I do not mean to say that the exact *proportional* freedom of the water from organic matter will be represented by the figures given in these analyses, but I do think that they may indicate that certain samples are less pure than others, and so on. For the purpose of a simple comparison, these results will be almost as useful as absolute statements, for we may work on the basis, that the good quality of our Hydrant water has been satisfactorily demonstrated.

In passing I may mention that Mr. Waldie disputes the correctness of Dr. Macnamara's results as to amount of organic matter present in the water, but it would be quite as easy for me, with a knowledge of the progress of the last ten years, to dispute the correctness of Mr. Waldie's results, so that in both cases, the results of the old analyses as to organic matter are to be accepted as comparative statements, rather than actual truths. It must be clearly understood, however, that I have no wish to under-rate the value of the work done by Dr. Macnamara and by Mr. Waldie; far from it, I believe that the results criticized are as accurate and reliable as could be obtained by the processes then known, and in those portions of the work, where the methods of analysis have not been changed, I think we may rely, with certainty, on the accuracy of the results given.

In the face of the above facts, I may be pardoned, if in considering these old analyses I draw more particular attention to the determination of the inorganic substances present, where the methods of analysis have scarcely changed, and refer less to the determinations of the organic substances present in the water.

In tidal water, that is water of which a part at least has been derived from the sea, sodium chloride, or common salt, is a prominent ingredient. In the table given on p. 120, it will be seen that sea water contains no less than 1975·6 parts of chlorine per hundred thousand of water; this substance, on the other hand, is present in very minute quantities in the true river water, and hence we have a crucial test to apply, in order to determine the presence or absence of tidal water in the samples in question. It may here also be well to remark that the process of analysis for the determination of chlorine in waters has not changed since the period when the analyses by Dr. Macnamara and Mr. Waldie were made, and therefore we may entirely rely on the accuracy of the results given as to the amounts of this constituent present in the samples of water analysed.

In the following table I quote four sets of analyses made by Dr. Macnamara of water collected, *at low water in each case*, from three different points in the river, namely, at Chinsurah, Pultah and off Cossipore, (one mile above Baug Bazar Bridge). For the sake of comparison I have added to the table some of the numbers obtained in the regular analysis of water for the year 1878.

Analyses of Water taken in the middle of Stream six feet from Surface.

Results expressed in parts per 100,000 *of water.*

	Constituent.	Low water. 17th December 1861.	Low water. 15th March 1862.	Low water. 12th June 1862.	Low water. 8th September 1862.
Chinsurah.	Total solid residue from filtered water	26·6	27·9	..	12·9
	Organic matter	6·0	5·6	..	2·6
	Insoluble earthy salts	16·9	19·9	..	8·0
	Soluble salts	3·6	1·9	..	1·5
	Sodium chloride	..	1·1	..	0·8
Pultah.	Total solid residue from filtered water	23·1	27·3	26·3	14·6
	Organic matter	6·0	5·6	5·0	2 1
	Insoluble earthy salts	14·1	19.0	17·0	8·7
	Soluble salts	2·7	1·7	3 6	2·0
	Sodium chloride	..	1·1	3·6	0·9
Cossipore.	Total solid residue from filtered water	24·6	34·7	97·1	13·3
	Organic matter	5·0	5·6	11·9	2·1
	Insoluble earthy salts	16·7	19·3	16·4	9·0
	Soluble salts	2·6	8·9	67·6	1·3
	Sodium chloride	..	7·6	55·7	..
		1st December 1878.	1st March 1878.	1st June 1878.	1st September 1878.
Hydrant water.	Total solid residue	16·80	24·34	15·16	11·12
	Carbon and nitrogen of organic matter ..	0·158	0·164	0·111	0·124
	Sodium chloride	1·01	1·87	1·70	0·79

An examination of this table and of the numbers given in previous parts of this paper shows clearly that the pure river water, *i. e.*, the present hydrant water never contains more than two or at the outside three parts of sodium chloride per 100,000 of water. This is proved by Dr. Macnamara's analyses of the water at Chinsurah and Pultah, and also by the numbers obtained weekly and monthly by myself.

When however the analyses of Cossipore water are considered, it will be seen that, whilst at low water in September and December, its composition is very similar to that of pure river water collected higher up : in March and more particularly in June, there are very striking differences. Thus on June 12th 1862 whilst at Pultah, there were only 26 parts of solid impurity and 3·6 parts of sodium chloride or salt in every 100,000 parts of water, at Cossipore (one mile above Baug Bazar Bridge) on the same day, and *at low water*, in the same volume there were no less than 97·1 parts of solid impurity, of which 55·7 parts were sodium chloride. This clearly indicates that on this occasion, there was a very large admixture of tidal water with the river water. Dr. Macnamara's results, as to the amount of organic matter, also appear to show that in June, there was much more present in the Cossipore water than in that collected at Pultah, and this is really what would be expected to be the case. The ratio of the organic matter shown in the two instances is greater than 2 to 1, and I think that this difference must indicate that the water at Cossipore did contain an excess of organic matter over that contained at Pultah. The *absolute* amounts of organic matter were, we now know, very much smaller than the numbers given in the table, but we can probably rely, to a certain extent, on the *relative* correctness of the numbers given.

There appears then to be no escape from the conclusion which Dr. Macnamara draws in his criticism of these results when he says—"the water (at Cossipore) during March, April, May and June is largely intermixed with the saline matters of the sea water and the sewerage of Calcutta, and during that time is unfit for human consumption."

As before pointed out the sewage contamination would be very much less at the present time than it was then, but I have tried to prove that we cannot have an admixture of tidal water without at the same time having organic and sewage contamination. I have no doubt that during the rains when a powerful stream is running down, the water at Cossipore may be nearly as pure as that at Pultah, but I think that Dr. Macnamara's analyses alone prove that, during the hot weather months, the water at Cossipore is by no means pure enough to be selected as a water-supply.

Turning now to the analyses made by Mr. Waldie, it appears to me that they essentially confirm the results given by Dr. Macnamara. The water tested by Mr. Waldie was taken usually from the river at Burranagur, which is said to be two miles above Cossipore. Here on June 14th, 1866 at 11-5 A. M., (*at low water*) 30·7 parts of solid matter, of which 14·5 parts were sodium chloride, were found; again on May 1866, two hours before the commencement of tide, there were 21·50 parts of salt present; on May 2nd 1866, there were 15·50 parts of salt at ebb-tide, and on June 1st 1866 at nearly low water, 16·50 parts of sodium chloride were found; these numbers being the quantities present in 100,000 parts of water.

With regard to organic matter also Mr. Waldie's results, though showing much less organic matter than Dr. Macnamara's analyses, to a great extent confirm his statements, and prove that as a rule, there is a larger amount of organic matter in the water collected at ebb-tide off Burranagur, than in the water collected at higher points of the river. The numbers above quoted show unmistakeably that at *two miles above Cossipore* during the hot season, there is a decided admixture of tidal water and probably of sewage contamination with the pure river water, and that this is the case even with samples collected at low water.

The opinion of Dr. Macnamara as to the suitability of Cossipore water for drinking purposes, has already been given. I will now quote Mr. Waldie's remark in his general summary of results—"Can the supply be safely taken from the river at Cossipore? We can scarcely answer in the affirmative."

In conclusion, then, I may say that, so far as can be ascertained from the old analyses by Dr. Macnamara and Mr. Waldie, and from my own results, it is my opinion—

That during the rainy season, and whilst the river is in *full* stream, the water collected two miles above Cossipore, or perhaps even at Cossipore, could probably be used as a fairly safe water-supply.

That during the hot weather months, if the water is collected two miles above Cossipore, even at five hours' ebb, there will frequently, if not always, be contamination with tidal water to an extent, which unfits it for a safe water-supply, and the water will be contaminated to a still greater degree if collected at Cossipore.

That this tidal contamination would involve also organic contamination to a considerable extent, and that, as pointed out in a previous part of this paper, such organic or sewage contamination cannot become oxidized or destroyed during the flow of the water, nor can the water be purified by the ordinary processes of settling, filtration through sand etc. so as to render it a safe supply for domestic purposes. Such water therefore would be eminently unsafe for potable purposes and should be at once condemned.

That unless contrary evidence is furnished, the proposed new sources of supply are too near to the mouth of the river and to Calcutta, and consequently that it is strongly desirable that the extension of the water supply should be carried out on the same principle as formerly, and that the water should always be collected at Pultah, and not at the other points which have been suggested.